manufacturing

The future of
manufacturing
is at
NASA
Marshall Space
Flight Center

Manufacturing technologies we need to reach the stars are the engines to drive America's future.

Manufacturing companies must stay on the cutting edge if they are going to be competitive in the global marketplace. Competitive advantage requires state-of-the-art facilities and equipment to design, assemble, and test new or improved products. NASA's Marshall Space Flight Center has spent years building these capabilities to fulfill the manufacturing needs of the space program.

Our world-class facilities include both innovative processes developed at Marshall and a vast range of cutting-edge technologies that may be hard to find or too costly for manufacturers to maintain in-house. Our vast range of integrated capabilities may be able to give your company a needed boost in transitioning into new processes and successfully moving forward.

We invite you to partner with Marshall to develop new manufacturing processes, learn from our expertise, or benefit from our unique and comprehensive facilities. This information booklet describes our expertise in the following areas of manufacturing:

- *Design*
- *Advanced manufacturing processes*
- *Testing and analysis.*

Bringing Babies into the World More Safely with Space Technology

The national investment in manufacturing equipment and expertise at NASA's Marshall Space Flight Center benefits not only the space program but also commercial industry—and someday it may benefit newborn babies. Marshall has partnered with Dr. Jason H. Collins of the Pregnancy Institute in Slidell, Louisiana, and with Prism, a San Antonio manufacturer of medical products, to improve the obstetric forceps used to position an infant in the mother's womb prior to delivery. Traditional stainless steel forceps can place excessive force on the infant's head, which can result in damage or injury to the newborn. Marshall is working to combine several space technologies to improve the device's design.

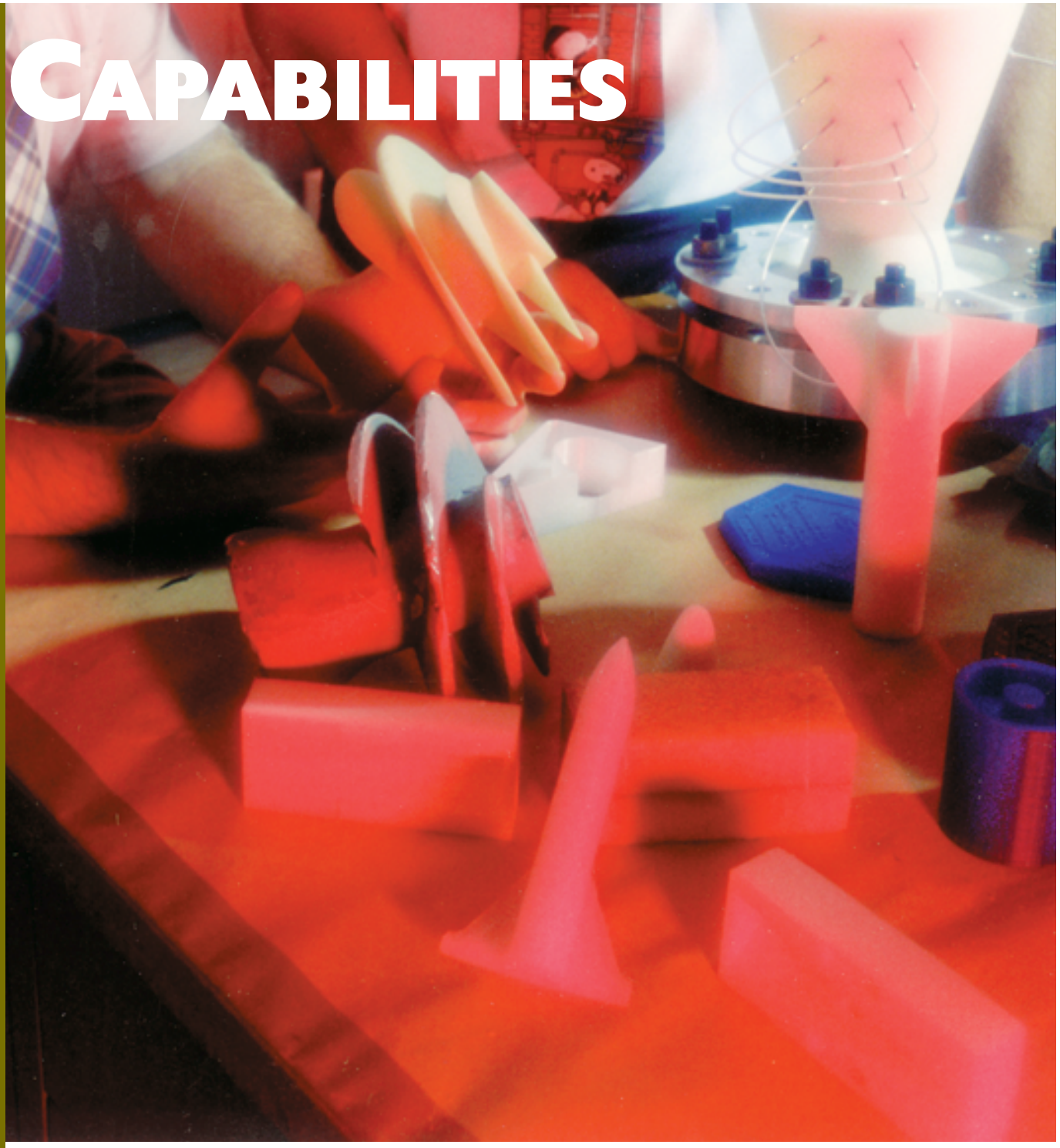
"Partnering with Marshall puts us at the forefront of manufacturing technology," says Prism CEO Merle Smith. "Working together, we can use this technology to make infant delivery safer." This booklet describes other technologies available at Marshall to help you develop new or improve existing products and processes.

Marshall's comprehensive manufacturing capabilities can benefit the commercial industries that manufacture our nation's products:

- Aircraft
- Automobiles
- Bridges and tunnels
- Buildings
- Clean rooms
- Consumer electronics
- Industrial equipment
- Marine craft
- Medical equipment
- Recreational equipment
- Satellites
- Spacecraft
- Structural elements
- Tanks
- Transportation equipment.

Design

Capabilities



As any manufacturer can attest, a good design enables a product to be manufactured efficiently, quickly, and precisely. At Marshall, we have acquired the tools essential for product design to support advanced manufacturing processes. Our computer-aided design, engineering, and manufacturing facilities, as well as our rapid prototyping capabilities, can save you time and money. We also have expertise in thermal, structural dynamics, fluid flow, life support, aero heating, optics, and control design analysis.

Computer-Aided Design, Engineering, and Manufacturing

Computer-aided design (CAD), engineering (CAE), and manufacturing (CAM) are powerful tools for improving manufacturing processes. Marshall's expertise in CAD/CAE/CAM programs can help your engineers design, optimize, and verify manufacturing processes interactively using three-dimensional computer graphics.

Computerized design information is translated into numerical machine code or robotic control language to program processing equipment. You can use our CAD/CAE/CAM capabilities for feasibility studies to evaluate the potential for manufacturing success before you make a capital investment. These computer-aided tools also can be used during process planning to reduce setup time and waste of materials.

Rapid Prototyping

Rapid prototyping saves time and money by eliminating the need for mock-ups and other intermediate steps that often slow the transition from the design stage to manufacturing. You can produce models, functional parts, and castings with Marshall's rapid prototyping systems:

Stereolithography

Photocurable liquid resin and a low-power laser form transparent concept models, investment castings, and components.

Laminated Object Manufacturing

Layers of paper with adhesive backing take computer models to 3D concept models. The material can be sanded and painted like wood, and the system is fast and accurate.

Fused Deposition Modeling

A hot gun shapes model parts from high-temperature materials, ceramics, or plastics. The three-dimensional output can be used as conceptual models, functional models, and castings.

3D Inkjet Prototyping

This systems prints with hot wax for small, intricate conceptual models and wax casting patterns with high accuracy and excellent surface finish.

Selective Laser Sintering

Powder and a laser build conceptual and functional models and castings using waxes, castable polycarbonate, foundry sand, nylons, rubber-type material, and semimetallics.

Marshall researchers are exploring how advanced materials and rapid tooling can further improve rapid prototyping as a design technique. Manufacturers and other companies interested in pursuing the future of rapid prototyping are encouraged to contact Marshall.

Virtual Reality at Marshall

Marshall's CAD/CAE/CAM and rapid prototyping technologies enable you to design a product that is easily manufactured—but a product's usability, ergonomics, and safety may also be important to your customers. Virtual reality (VR) allows you to test a product before manufacture, eliminating design flaws, reducing costs, and bringing your products to market faster.

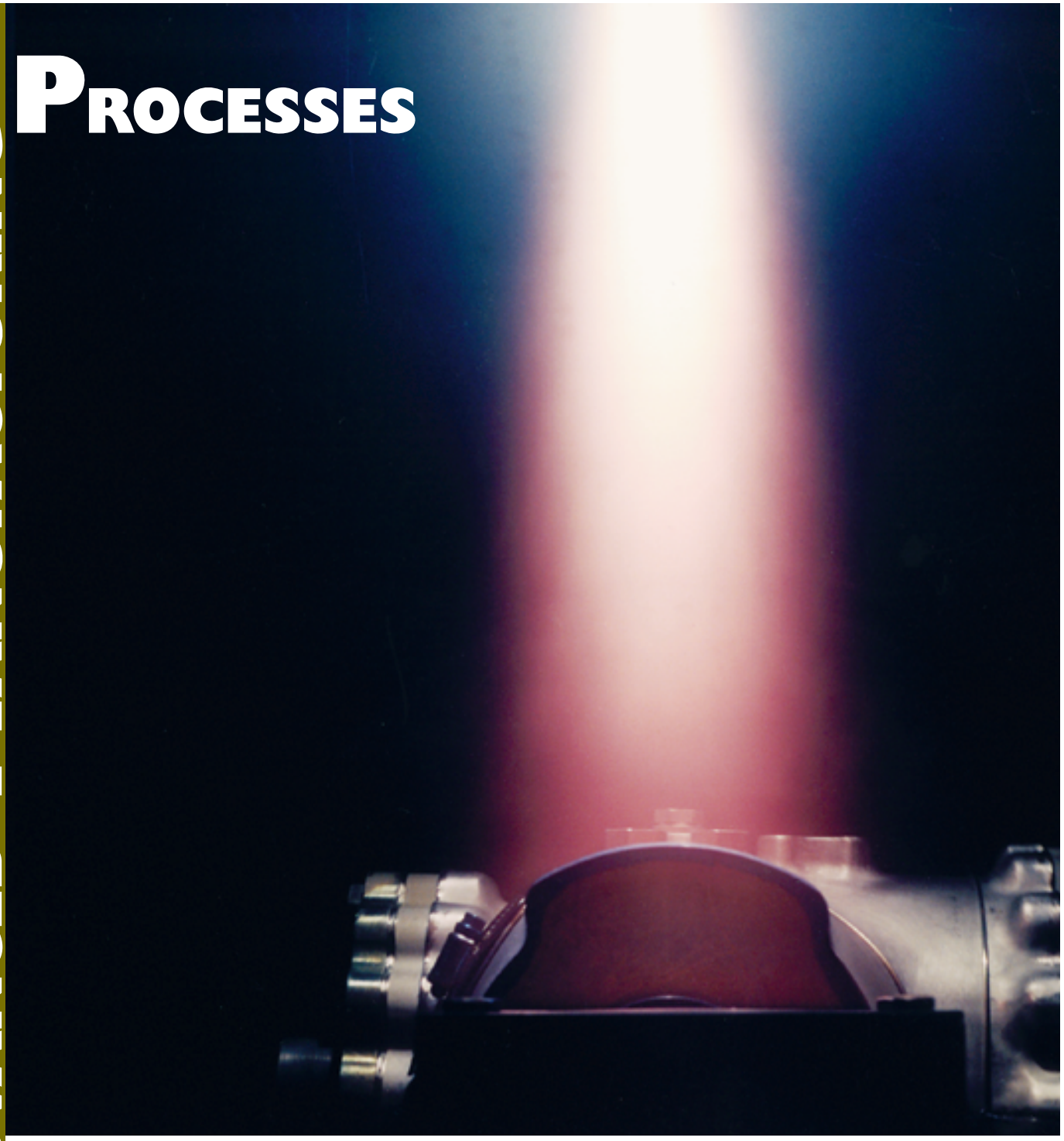
VR can be used in a variety of manufacturing applications:

- Training employees on newly developed processes
- Testing redesigned recreational equipment
- Analyzing the ergonomic compatibility of a new automobile interior, cell phone design, or industrial equipment
- Analyzing a design concept
- Performing human factors evaluation in various designs
- Visualizing hidden parts or equipment
- Marketing new products

Marshall's VR facilities complement our other manufacturing capabilities to let you move easily from design to testing and redesign to final production—all in the same place.

Advanced Manufacturing

Processes



To stay competitive in industry, you need the latest techniques to produce high-quality parts. But these techniques often require a capital investment that most manufacturers cannot afford. Marshall houses an impressive breadth of equipment that is further enhanced by resident technology and expertise for many novel and unique processes.

Advanced Composites Manufacturing

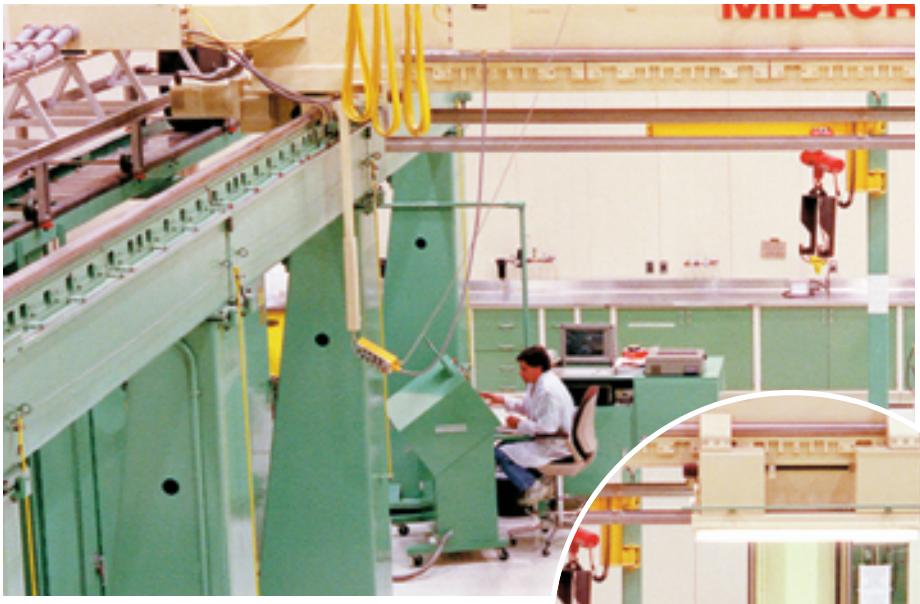
In an effort to make NASA's launch vehicles lighter, stronger, and more durable, Marshall has acquired a diverse range of equipment and experience in manufacturing composite parts. Marshall welcomes interest from companies wanting to use these technologies in various manufacturing applications. Composites can be used in other transportation vehicles and in recreational equipment, such as tennis rackets, fishing rods, skis, boat hulls, and golf clubs.

Tape Wrap

Using extreme heat and pressure to consolidate many layers into a uniform part, Marshall's computer-controlled tape wrap system can be used to manufacture conical geometries, such as nozzles, up to 2.5 m long and 1.5 m in diameter.

Commercial Uses

- Pipes
- Pressure vessels
- High-temperature ablative coatings.



Tape Laying

This system for highly controlled and precise tape laying on flat or contoured surfaces has 10 axes and 3 sensory systems.

Commercial Uses

- Garage doors
- Equipment racks
- Complex, single-part geometries.

Composite Laminates Optimization

Computer simulations allow you to design high-strength and low-weight composite laminates by varying the number of composite plies, the stacking sequence, the number and location of attachment bolts, and honeycomb size and width.

Commercial Uses

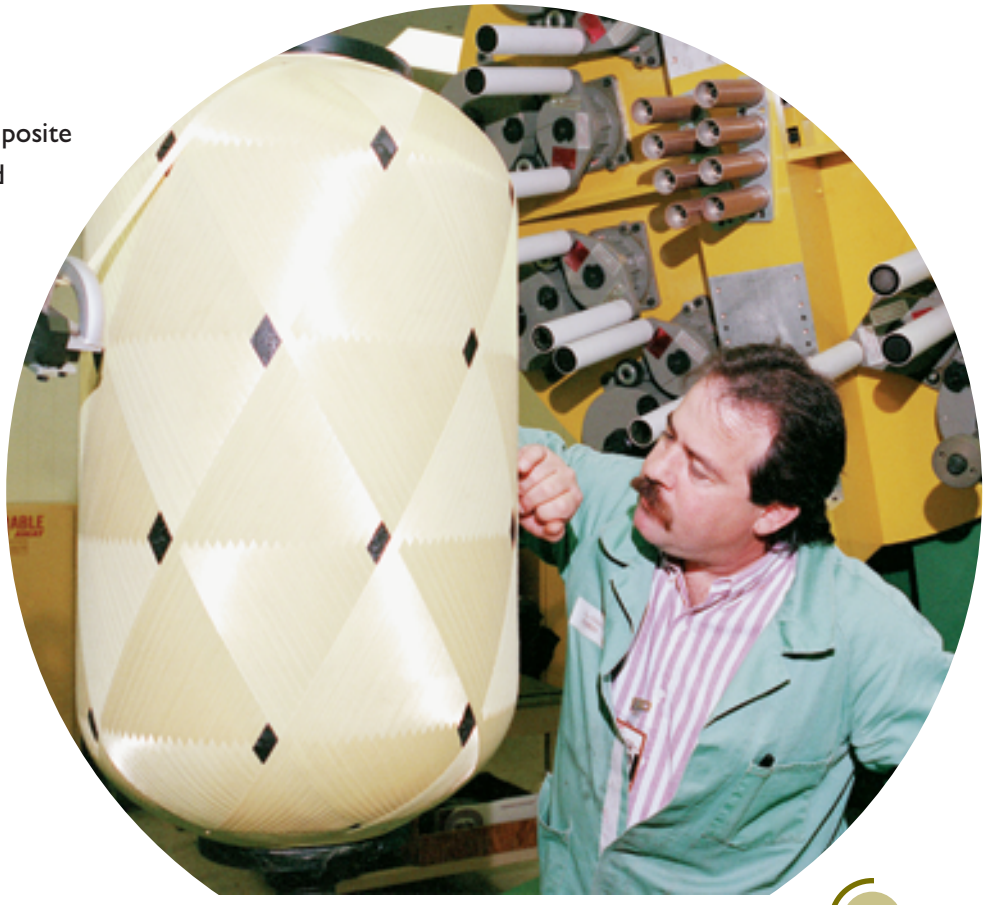
- Aircraft, automotive, and marine vehicles
- Bridges and other structures
- Golf clubs, racquets, bike frames and components, paddles, and other sports equipment.

Filament Winding

Cylindrical and helical composite parts up to 4.5 m long and 2 m in diameter can be manufactured in helical or polar patterns.

Commercial Uses

- Telescopes
- Microscopes
- Tanks
- Piping.



Advanced Welding Techniques

Manufacturing spacecraft and other flight hardware for NASA's space program often requires the welding of high-performance alloys. As a result, Marshall has developed extensive welding capabilities that are at the forefront of manufacturing. These welding techniques can also be used in the automotive and other sophisticated manufacturing industries. Companies interested in applying these technologies to their industry are encouraged to contact Marshall.

Variable Polarity Plasma Arc Welding

Using high-velocity argon plasma to penetrate aluminum weld seams, this technique removes contaminants from the joint and eliminates internal defects within welds.

Commercial Uses

- Heavy-wall aluminum tanks
- Missile cryotanks
- High-quality welds.

Vertical Weld Tool

Cylinders up to 4.5 m long and greater than 3 m in diameter can be welded with this tool. The vertical weld tool provides a test bed for tooling and welding process development using arc welding and friction stir welding.

Commercial Uses

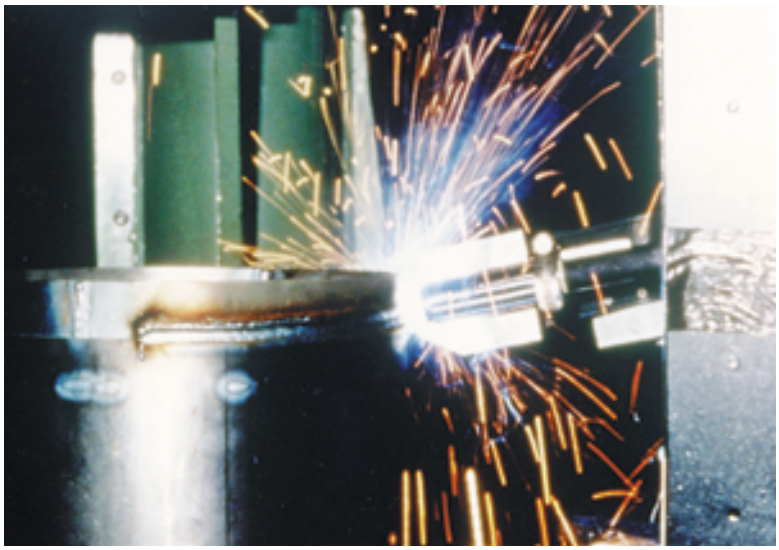
- Welding development in new alloys
- Testing of tank assemblies
- Testing of welding controls.

Tank Welding Application Tool

With its automated leveling jacks, internal and external work platforms, and machining station for weld joint preparation, this technology can weld tanks up to 8.5 m in diameter.

Commercial Uses

- Aluminum welding up to 35 mm thick
- Developing large tank assemblies.



Robotic Welding

Marshall's robotic welding system includes five-, six-, and seven-axis robot arms; two-axis part positioning tables; and CAD/CAM systems to calculate complex movements. Robotic welding allows irregular weld seams to be followed.

Commercial Uses

- Joining irregularly shaped parts
- Developing "quick-change" robot tools
- Developing sensor-based robot welding.

Friction Stir Welding

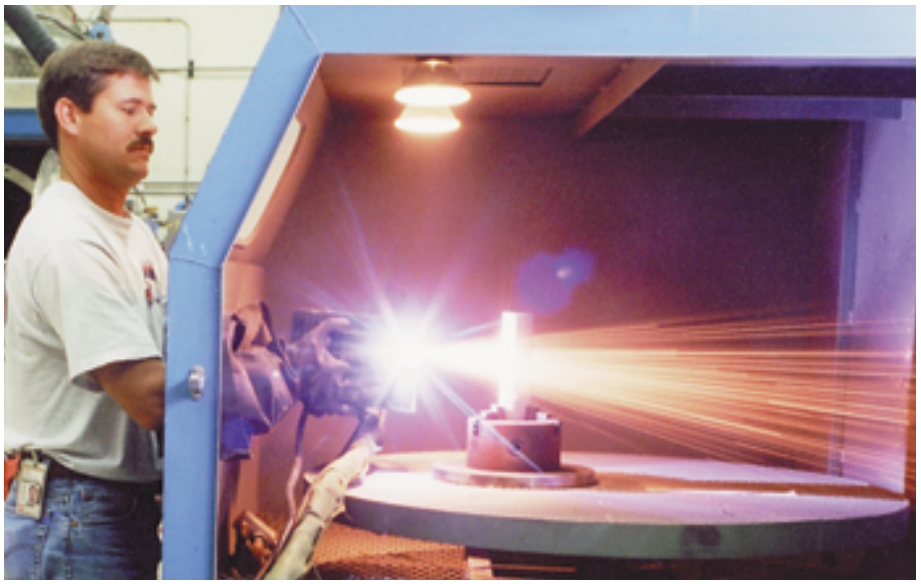
This new welding process is ideal for making high-quality welds in aluminum alloys, even those previously considered "unweldable." Marshall's facilities can produce linear welds up to 4.5 m long, with thicknesses ranging from 2 mm to 18 mm. A unique pin-tool control allows welding parts with changing joint thickness.

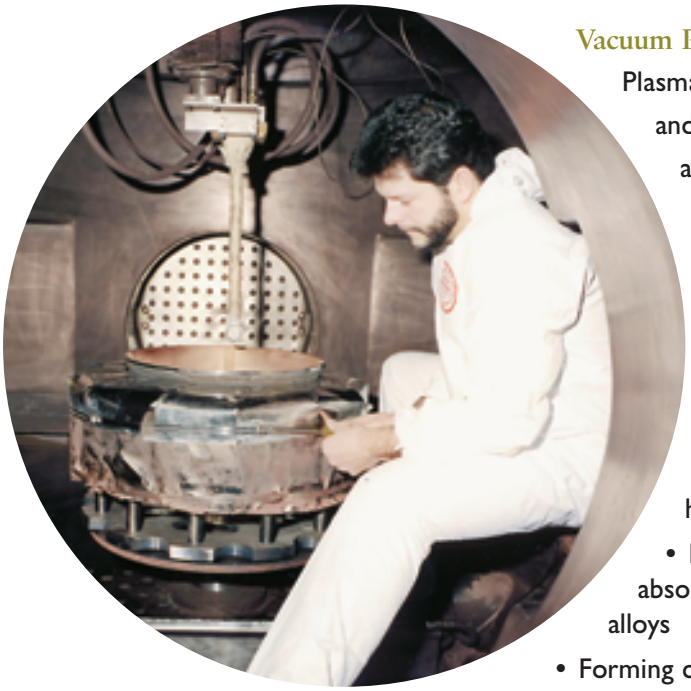
Commercial Uses

- Welding 7000-series alloys
- Assembling large tank structures.

Thermal Spray Processing

Thermal spray enables coatings of many different materials to be applied exactly where they are needed. We have vast expertise with a variety of materials and three thermal spray processing methods that can be applied to the aerospace, electric power generation, automotive, biomedical, marine, and structural manufacturing industries. By keeping the use of hazardous materials to a minimum, these techniques are environmentally friendly.





Vacuum Plasma Spray

Plasma-generating equipment melts and accelerates coating materials and deposits them onto the substrate.

Commercial Uses

- Wear-resistant coatings
- Thermal protection for turbine blades
- Copper bond coats on titanium castings for flight hardware
- Forming solar thermal engine absorber cavities from tungsten alloys
- Forming containment cartridges for growth of single crystal semiconductors.

Wire Arc Spray

Two advancing wires are melted by an electrical arc conducted across wire tips, and the molten metal droplets are atomized by high-velocity gas.

Commercial Uses

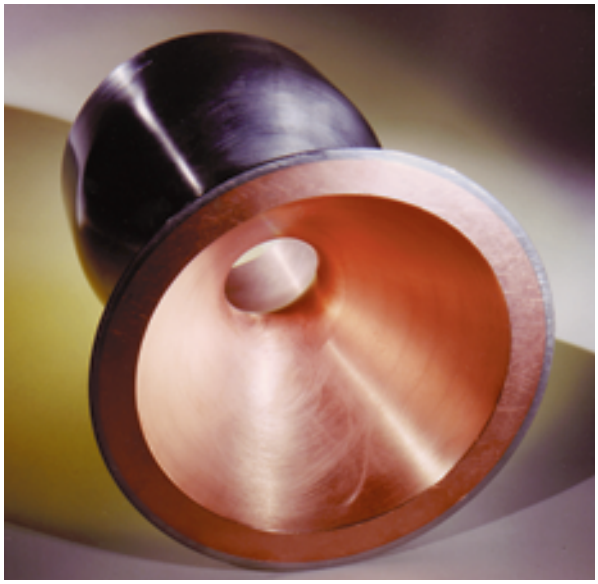
- Anodic corrosion protection
- Cryogenic duct primer
- Bond coatings
- Electromagnetic interference, wear, and erosion coatings.

High-Velocity Oxyfuel Spray

Powder is injected and entrained in a carbon-based fuel/oxygen combustion flame, where it melts and accelerates. The deposited coatings are dense and adhere well to substrate surfaces.

Commercial Uses

- Wear-resistant coatings
- Material build-up or repair of sealing and wear surfaces
- Corrosion protection
- Hydrogen environment embrittlement protective coatings.



Robotic Water Blasting

Marshall's water blast stripping and cleaning system is precise, environmentally friendly, and safe. Coatings can be removed without damage to the substrate. Multiple coatings can be removed individually. Water blasting eliminates the need for solvents, and the robotic operation keeps technicians safe. This technology can be used by the aerospace, automotive, and recreational equipment industries, as well as in composite job shops and on pressure vessels. Our facility has the following capabilities:

- Three pumping systems
  - 20 gal/min at 15,000 psi
  - 12 gal/min at 36,000 psi
  - 3 gal/min at 15,000 psi, with baking soda injected
- Nozzle manipulated by six-axis robot
- Pentium-based computer-controlled blasting operations.

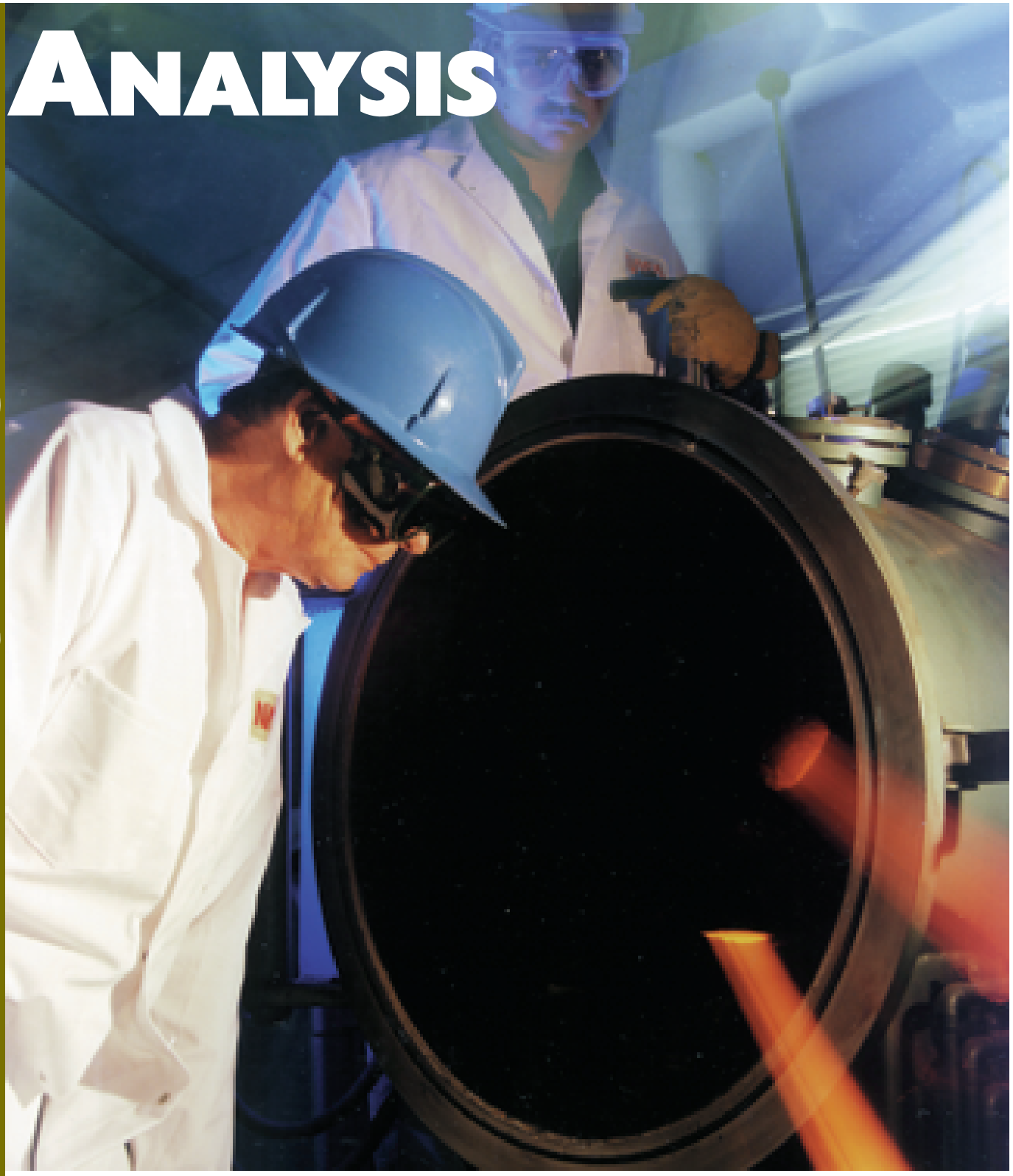
High-Speed Machining

Increasing production rates without dramatically increasing costs improves your bottom line. High-speed machining, which can be used in die cast mold machining and skin mills, is one way to increase production economically. Marshall has taken a step into the future with its hydraulic-driven spindle, which offers real benefits over electro-driven spindles:

- Produces less heat, eliminating need for coolant and enabling thin-wall machining
- Offers excellent clamping power with its light spindle
- Enables use of a smaller precision bearing
- Features fluid cushioning, so the tool is less likely to break
- Provides faster and less expensive machining than other techniques.

Industries interested in partnering with Marshall in defining the future of high-speed manufacturing are encouraged to contact us.

Testing and Analysis



Manufactured parts often require extensive testing and analysis to ensure they will perform as expected. Marshall maintains sophisticated testing and analysis capabilities for NASA mission requirements. These capabilities and Marshall's expertise can benefit U.S. manufacturers in the commercial aerospace and other industries. Companies are encouraged to contact us to discuss partnership opportunities.

Failure Analysis

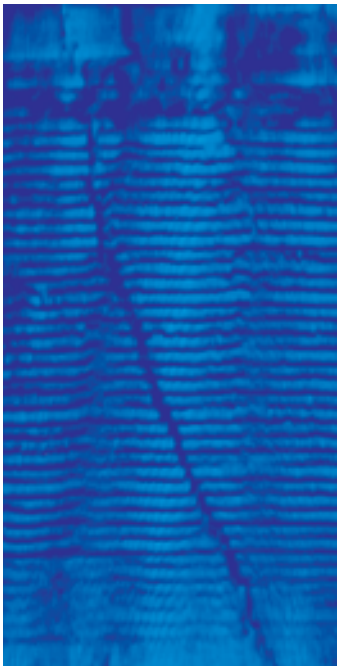
Marshall offers a full range of diagnostic equipment and facilities for failure investigation—from scanning electron microscopes to metallographic analysis to corrosion laboratories. In addition, the Failure Analysis Database provides detailed information on all NASA analyses performed for various materials and components—including how they performed and how problems were solved. You can use this information to avoid failure in your products.

Fracture Mechanics

In some manufacturing applications, even the smallest fracture can be deadly. Marshall has the equipment and expertise to identify both ductile and nonlinear fractures and to assess how detrimental they may be. Marshall also uses finite element modeling to determine structural integrity and stress loads.

Commercial Uses

- Oil refineries and rigs
- Power plants
- Pressure vessels
- Tanks
- Trucks and aircraft
- Bridges
- Equipment.



Computed Tomography

Marshall's computed tomography capabilities enable the nondestructive evaluation of advanced composite materials, aerospace and automotive castings, and other mechanical and structural components up to 6 ft high, 4 ft in diameter, and weighing 3,700 lbs. These technologies can be combined with our rapid prototyping technologies to improve the progress through design, testing, redesign, and production.

Capabilities

- Multiple radiation sources—420 KeV tube and 2 MeV linear accelerator X-ray sources
- Multiple scan geometries
- Automated dimensional analysis for voids and defects
- Exportable images for easy CD-ROM distribution.

Electromagnetic Interference Testing

Understanding the electromagnetic environments your products may experience and how they will perform can mean the difference between a fully functioning electronic device and an inoperative system. Shielded rooms can be used to test equipment for 208/120 VAC 3 PH 60 Hz, 28 VDC, and 120 VDC circuits. Units that demand up to 28 VDC 200 A and 120 VDC 50 A can be tested. These facilities, when combined with our unique capabilities, help make Marshall a comprehensive facility.

Commercial Testing

- Electromagnetic interference and compatibility of aerospace systems
- Embedded central processing units (CPUs) in
  - Aircraft
  - Automobiles
  - Appliances
  - Manufacturing equipment
- Electronics shielding for processors.

Analytical and General Chemistry

Most striking about Marshall's manufacturing capabilities is the broad range of technologies all available in one place. A good example of this is our analytical and general chemistry facilities. By providing both standard and hard-to-find chemistry equipment in combination with our unique capabilities, Marshall can meet all your advanced manufacturing needs.

Capabilities

- Spectral photometers
- Fourier transform infrared spectrometers
- Inductively coupled plasma mass spectrometers
- Optical emission spectrometers
- Scanning electron microscopes
- X-ray photoelectron spectrometers
- Alloy analyzers
- Mass spectrometers
- Gas chromotographers
- Wet chemistry capabilities
- Metallurgical analysis instruments.

Environment Protection

Marshall is leading NASA's effort to develop environmentally friendly adhesives, degreasers, dewaxers, fuels, paints and paint strippers, primers, insulation, flushing and cleaning agents, precision-cleaning materials, blowing agents, brazing alloys, and propulsion fuels. To accomplish this, Marshall has developed extensive expertise in testing the environmental impact of various liquids, materials, and processes.

Compliance is crucial when it comes to environmental regulations. Let our expertise help you ensure that your manufacturing processes are environmentally friendly.

Contamination Detection

The science of contamination detection is advancing, and Marshall is leading the way with its particulate and molecular contamination monitoring. We have the equipment and capabilities for performing various contamination research activities in manufacturing, clean room, and simulated space environments.

Materials Contamination

Marshall can qualify materials for offgassing using standard and unique test instrumentation.

Surface Contamination

Our capabilities include optically stimulated electron emission, Fourier transform infrared spectrometers, near infrared spectrometers, ellipsometers, and ultraviolet fluorometers.

Contamination Control

Scientists have expertise in contamination control implementation plans, materials selection and control, and monitoring/evaluating facility cleanliness.

Hydrogen Testing

To confirm the performance of materials in the hydrogen-rich environment of launch and space flight, Marshall has the facilities to provide a variety of hydrogen testing options. Mechanical tests include tensile, strain to crack, fatigue, fracture toughness, creep, shear, compression, bearing, four-point bend, cryogenic exposure, gaseous exposure, and thermal conductivity.

Combustion Research

We have the capabilities to screen your materials for their combustibility and flammability properties and for their performance in oxygen-rich environments through a variety of tests:

- Upward flame propagation
- Electrical wire insulation flammability
- Simulated panel or major assembly flammability
- Mechanical impact
- Arc tracking
- Frictional heating
- Upward flammability of materials in gaseous oxygen.

Pyrotechnic Testing

Every spacecraft has countless exploding bolts, state separations, air tools, and systems that undergo pyrotechnic shock. Marshall's Pyrotechnic Shock Test Facility can generate dynamic transients with explosive materials for shock levels of up to 30,000 g and 10 kHz. In addition, we have extensive expertise in designing pyrotechnic systems. Our capabilities can be used for seat belt and airbag systems, shape charges, and emergency rescue tools.

High-Heat Flux Testing

Composite materials in space flight can be subjected to temperatures exceeding 5,500 °C and high heating rates. Marshall has developed a plasma torch to test the performance of composites in these conditions. These tests are quick, inexpensive, and can be used to test instruments and materials for high-temperature applications.

Thermal Testing

Marshall has five computer-controlled thermal humidity chambers for testing a product's ability to withstand environmental extremes during long-term storage or outdoor use. These chambers offer a temperature testing range of –100 to 350 °F, and a relative humidity range from 5% to 95%. Marshall's thermal vacuum chambers simulate space environment conditions. Items up to 20 ft in diameter can be taken from –290 to 300 °F at pressures down to $1x10^{-8}$ Torr. Clean room capabilities enable testing of high-precision optical systems.

Structural and Flow Dynamics

To support NASA's space missions, Marshall has developed extensive expertise and facilities to ensure the structural integrity of its spacecraft and to understand the aerodynamic and aerothermal forces involved in launch, flight, and reentry. These capabilities offer extensive benefits to manufacturers of automobiles, aircraft, bridges, buildings, marine craft, and transportation equipment.

Structural Dynamics

Marshall has facilities to conduct a variety of structural tests:

- Quasi-static load tests
- Vibration tests
- Vibroacoustic tests
- Pyrotechnic shock tests
- Hazardous structural tests
- Cryogenic structural tests
- Modal tests.

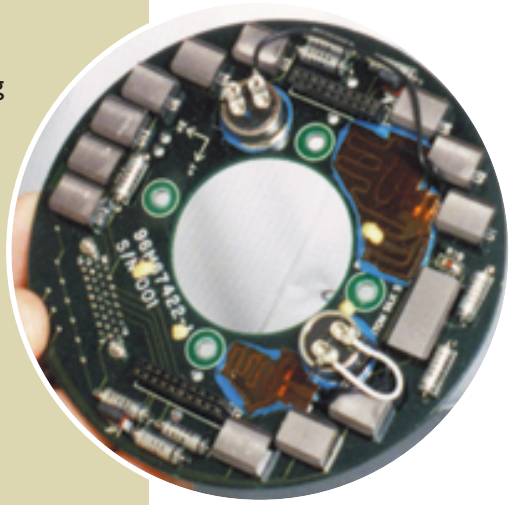
Flow Dynamics

Marshall offers complex pathflow visualization to give engineers a better understanding of their machines:

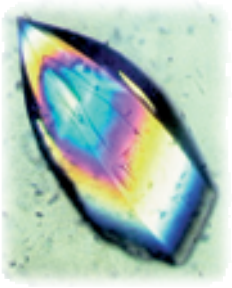
- Wind tunnel tests
- Engine water and air flow tests
- Pump tests
- Nozzle tests
- Turbine tests
- Thermal transient analysis.

Electronics

Marshall has extensive experience ensuring the integrity and functionality of a spacecraft's electrical power system and parts. Our power electronics experts have experience with everything from fractional wattage power supplies to multikilowatt power systems. From solar arrays to batteries to supercapacitors, our expertise and laboratories can serve your electronics needs.



Developing Advanced Materials in Space



The next generation of supercomputers will use light instead of electricity to transmit information. The tremendous interest in this field has created a demand for materials that have the necessary optical properties.

Marshall Space Flight Center has been studying two important classes of organic nonlinear optical (NLO) materials—phthalocyanins and polydiacetylenes—for photonic devices, such as optical switches, optical memories, and logic gates.

NLO materials must be processed into pure, highly uniform, molecularly oriented, and defect-free crystals or thin films. On Earth, gravity causes the natural convection and sedimentation that lead to undesirable mixing, fluid flows, and settling. In space, however, scientists can escape these effects and study the processing of NLO materials under more ideal conditions. Phthalocyanin, polydiacetylene, and dicyanovinyl analine thin films have been grown aboard the Space Shuttle.

Technology Transfer at NASA Marshall Space Flight Center

This information package has been assembled as part of NASA Marshall Space Flight Center's technology transfer program. The primary goal of the technology transfer process at Marshall is to encourage broader utilization of Marshall-developed technologies and unique combination of facilities in the U.S. industrial community.

We invite you to contact Marshall to discuss possible partnership opportunities and availability of facilities.

NP-1998-10-74-MSFC